COMPUTER-BASED INSTRUMENTATION SYSTEM FOR TEMPERATURE MEASUREMENT USING THERMOCOUPLE IN MATLAB APPLICATION

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ABSTRACT

A computer- based instrumentation system has been developed for temperature measurement. The measurement is using thermocouple type K. Thermocouple will detect temperature then send the input to temperature transmitter. Temperature transmitter will accept the input from thermocouple or dc milivolt input and convert it to a 4 to 20mA signal for transmission. Then, the temperature transmitter connected to data acquisition (PCI1710HG) that used to read data from the temperature transmitter. SIMULINK model is use to interface DAQ with MATLAB. Analog input from DAQ will transfer to MATLAB Workspace. The system is developed with MATLAB Graphical User Interface (GUI). GUI will capture data from workspace and then calculated average of actual output and output error. The process is continued by plotting five point temperature calibrations and error curve. The system also can do the evaluation of the uncertainty of temperature measurement. Uncertainty of measurement is the doubt that exists about the result of any measurement. The system allowed the user to save the plot and key in the data in excel. By implementing this system in Industrial Instrumentation class, the improvement and continuity of learning process will be achieved.

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CHAPTER 1

INTRODUCTION

1.1 Project Overview

Computer-based measurement systems are used in a wide variety of applications. Computer-based instrumentation for temperature is measure system that place the instrument's intelligence and measurement circuitry of temperature inside the computer. Instrument that use are digital thermometer 7563, ISOTECH Jupiter 650B,Yokogawa Temperature Transmitter (PT100),HART 375 Field Communicator and two thermocouples type k (one thermocouple as a reference and other one as a measured value).

Generally, thermocouple is a sensor for measuring temperature. Thermocouple operation is based on the physical principles that if two dissimilar metal wires are joined together and the point of joining is heated (or cooled), a voltage difference appears across the two unheated end. Type K thermocouples are made up of a positive Chromel wire and a negative Alumel wire. They are the most popular thermocouple type and offer a wide measurement range with good temperature precision. Thermocouple type k can read temperature in range -200 °C to +1200°C and develops approximately 0.04 mV/°C.

Data acquisition (DAQ) is the sampling of the real world to generate data that can be manipulated by a computer. In order to take measurements with computer-based DAQ hardware, temperature transmitter, signal conditioning equipment and software such as MATLAB is needed. DAQ typically involves acquisition of signals and waveforms and processing the signal to obtain desired information. In this project, PCI 1710HG will be use. The PCI-1710 Series are multifunction cards for the PCI bus. Their advanced circuit design provides higher quality and more functions, including the five most desired measurement and control functions: 12-bit A/D conversion, D/A conversion, digital input, digital output, and counter/timer [1].

MATLAB GUI is a high-level language and interactive environment that enables you to perform computationally intensive tasks faster than with traditional programming languages such as C, C++, and FORTRAN. MATLAB is a numerical computing environment and programming language. Created by Te Math Work, MATLAB allows, plotting of function and data, implementation of algorithms, creation of user interfaces, and interfacing with programs in other languages [2].

1.2 Problem Statement

The problem statement is to do the improvement or continuity of learning process. Before this student only do the experiment at lab and then insert the data and draw the graph manually. This will cause inaccurate results. So to solve this problem, we need to create a system using MATLAB which will produce high accuracy result. This system can use data for uncertainty evolution and plot five point temperature calibrations. It also uses to compare and measure temperature value and actual value and automatically calculate the output error and graphing for output error curve. So that, in future this system can be use for learning process.

1.3 Objectives

This project has three objectives. The first objective is to understand the basic measurement principles of temperature transmitter using thermocouple type k. This is very important to make more understand the basic of temperature measurement so that the project can do smoothly.

Second objective is to develop a hardware that can use to integrate signal from instrument to software. DAQ model PCI1710HG Advantech is used in this project. The basic operation of DAQ card is also need to be studied.

The third objective is to develop the system using MATLAB GUI for student to use in the future. The application software such as MATLAB GUI is the brain of DAQ system. The application of MATLAB GUI controls the DAQ hardware for acquiring data. Once the data is acquired, the MATLAB GUI can use to analyze and present the data.

1.4 Scopes

There are several scopes that need to be proposing in this project. First scope is to do the basic temperature measurement such as five point calibration of temperature transmitter. Calibrations are the process of determining the relation between the output of measuring instrument and the value of the input quantity or attribute a measurement standard.

The second scope is to integrate the signal from instrument to software, so the hardware is needed to be developed. Hardware that will be use is DAQ card which is a basic A/D converter coupled with an interface that allows a personal computer to control the actions of the A/D, as well as to capture the digital output information from the converter. A DAQ card is designed to plug directly into a personal computer's bus.

All the power required for the A/D converter and associated interface components is obtained directly from the PC bus.

Then the third scope is to create a program using MATLAB that can interface with the hardware component. The PC will read the data (temperature reading) from the Thermocouple reading using real time application. Then, the program that creates using MATLAB will do the evaluation of uncertainty of the measurement.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature on fundamentals and applications of data acquisition, instrumentation, and control to engineering and technology is very extensive. Today in any type of computer aided manufacturing project work and laboratory tests, precision and reliability of instrumentation and data acquisition techniques may cause major impacts on results and outcomes. Therefore, students in technology programs must gain knowledge and skills pertinent to their curriculum and job requirements when they need to obtain any type of physical or virtual data on manufacturing, testing, measurement, and protection areas [1].

2.2 MATLAB GUI Based Instrumentation System

At the simplest level, data acquisition can be accomplished manually using paper and pencil, recording readings from a multimeter or any other instrument. For some applications this form of data acquisition may be adequate. However, data recording applications that require large number of data readings where very frequent recordings are necessary must include instruments or microcontrollers to acquire and record data precisely [2].

After more than 20 years of development, MATLAB has evolved from a powerful matrix calculation application into a universal programming tool used extensively within scientific and engineering communities both commercial and academic. MATLAB versions 6.0 and 7.0 include functionality for developing advanced graphical user interfaces, GUIs, and real-time animation and graphics. GUI applications offer many advantages for users who wish to solve complex problems by providing interactivity and visual feedback. GUI development can apply in instrumentation and data Acquisition interfaces [3].

2.3 Graphical User Interface

The graphical user interface (GUI) is intended to give a view of the status of the data acquisition system and its sub-systems (e.g. Event Transfer, Event filter, Event builder, Back End, etc.) and to allow the user to control its operation. The GUI was developed not only for general users, such as shift operators, but also to provide DAQ experts the ability to control and debug the DAQ system. The run control system can have many GUIs associated with a particular experiment. However, only one GUI can be a master, capable of controlling the DAQ system. The rest of the GUIs will visualize the monitored information. In the run control environment the GUI is considered to be a software component and will have an associated agent in the platform to interact with the DAQ/control component agents [4].

2.4 Temperature calibration and measurement

2.41 Fundamental of Temperature Calibration

Temperature is one of the most frequently measured parameters in industrial processes. Wide varieties of mechanical and electrical thermometers are used to sense and control process temperatures. Regular calibration of these thermometers is critical to ensuring consistent quality of product manufactured, as well as providing regulatory compliance for some industries [5].

Most simply stated, temperature calibration consists of placing a thermometer under test into a known, stable temperature environment. A comparison is made between the actual temperature and the reading indicated by the thermometer under test and the difference is noted.

Adjustments can then be made either directly to the thermometer or to its readout. Electrical thermometers are adjusted by mathematically re-creating the coefficients used by SMART transmitters or other readout devices to translate their electrical output to temperature.

In industrial applications, the temperature environment is usually provided by a drywell, or "dry-block" calibrator, or a micro-bath. Both offer portability and a wide range of temperatures. Drywells use high stability metal blocks with drilled wells to accept the reference and UUT. Drywells typically cover ranges from -45°C to 1200°C and micro-baths cover ranges from -25°C to 200°C. Micro-baths are similar in size to drywells but use a small tank of stirred fluid instead of a metal block. Micro-baths offer significant advantages when calibrating short or odd shaped probes.

2.42 External and Internal Reference

Micro-baths and dry-wells have a built-in sensor to provide a feedback loop to the unit's controller and to provide a temperature reading to the user. The manufacturer of the heat source can calibrate this sensor so the unit displays a traceable temperature within a stated uncertainty.

The reference system, however, should be more accurate than the process system being calibrated. As a general rule, temperature uncertainties are larger at higher temperature. Using an internal reference is sometimes preferred because it requires fewer instruments and enhances portability for field applications. This block diagram is illustrated in Figure 2.1.

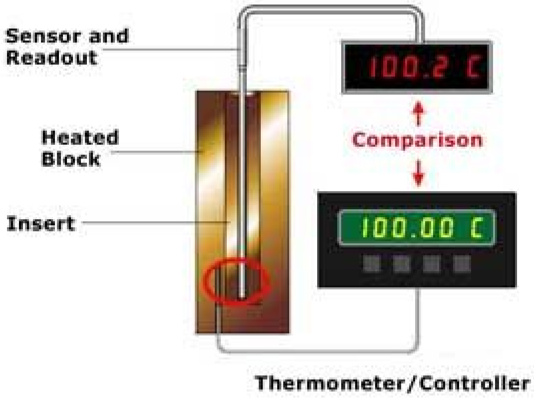

Figure 2.1: Heat source as reference standard

Uncertainty requirements are more rigorous, external references thermometers help improve system uncertainty (see Figure 2.2). Because external thermometers are more accurate, they increase the relative significance of other components of calibrations uncertainty, such as uniformity and stability. It is, of course, critical in any calibration to account for all sources of uncertainty in the process.

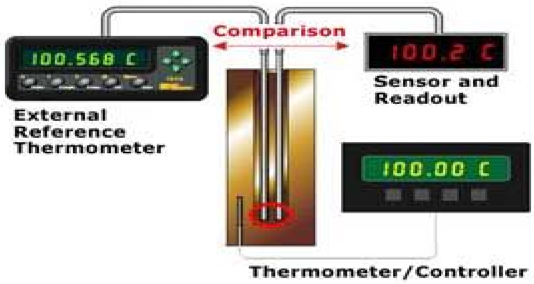

Figure 2.2: External preference standard

2.43 Component Calibrations

Most temperature sensors used in processes are read by transmitters, which send a 4 to 20 mA signal to a control panel, which then displays the temperature for process monitoring. Several calibration methodologies are used in the process plant and the most representative method being to calibrate the complete measurement system from sensor through transmitter to indicator or controller; alternatively each component of the measurement system can be individually calibrated.

The temperature sensor can be individually calibrated using a drywell or micro-bath heat source to simulate the process temperature. If the temperature sensor is electrical, a readout device measures its output.

The transmitter is calibrated using a precision simulator to generate the resistance or voltage output from the temperature sensor and input to the transmitter. The simulator also measures the resulting transmitter current or voltage output. The transmitter is adjusted to ensure that the output follows the input, e.g. for a 4 to 20 mA transmitter with a range of 50°C to 200°C, 4 mA corresponds to 50°C and 20 mA corresponds to 200°C. The simulator provides a wide range of input and output ranges to cover all resistance thermometer and thermocouple types.

The indicator or controller is also calibrated using a precision simulator to generate simulate the resistance or current input from the transmitter. The indicator or controller is adjusted so that the display variable matches the simulated input.

2.5 Software Interfacing

Data acquisition is the sampling of the real world to generate data that can be manipulated by a computer. Sometimes abbreviated DAQ or DAS, data acquisition typically involves acquisition of signals and waveforms and processing the signals to obtain desired information. The components of data acquisition systems include appropriate sensors that convert any measurement parameter to an electrical signal, which is acquired by data acquisition hardware.

Acquired data is displayed, analyzed, and stored on a computer, either using vendor supplied software, or custom displays and control can be developed using various text-based programming languages such as BASIC, C, Fortran, Java, Lisp, Pascal. It is a standard programming method to access data acquisition hardware. MATLAB provides a programming language but also built-in graphical tools and libraries for data acquisition and analysis.

2.51 Data Acquisition

Data acquisition begins with the physical phenomenon or physical property of an object (under investigation) to be measured. This physical property or phenomenon could be the temperature or temperature change of a room, the intensity or intensity change of a light source, the pressure inside a chamber, the force applied to an object, or many other things. An effective data acquisition system can measure all of these different properties or phenomena.

A transducer is a device that converts a physical property or phenomenon into a corresponding measurable electrical signal, such as voltage or current. The ability of a data acquisition system to measure different phenomena depends on the transducers to convert the physical phenomena into signals measurable by the data acquisition hardware.

2.52 DAQ Hardware

DAQ hardware is what usually interfaces between the signal and a PC. It could be in the form of modules that can be connected to the computer's ports (parallel, serial, USB, etc...) or cards connected to slots (PCI, ISA) in the mother board. Usually the space on the back of a PCI card is too small for all the connections needed, so an external breakout box is required. The cable between this Box and the PC is expensive due to the many wires and the required shielding and because it is exotic. DAQ-cards often contain multiple components (multiplexer, ADC, DAC, TTL-IO, high speed timers, RAM).

CHAPTER 3

HARDWARE DESIGN

3.1 Instrument

The process of create computer-based instrumentation for temperature can be divided in to three main parts. There are instruments, hardware and software. The instruments are digital thermometer 7563, ISOTECH Jupiter 650B, Yokogawa Temperature Transmitter (PT100), Yokogawa digital manometer MT 220, HART 375 Field Communicator and two thermocouples type k (one thermocouple as a reference and other one as a measured value).

3.1.1 Digital Thermometer 7563

The 7563 Digital Thermometer has 16 ranges of temperature sensors and DC, V, and Ohm measuring functions. Yokogawa-original A/D converter (feedback pulse width modulation method) features superior noise immunity, stability and high-speed sampling. In addition, versatile functions are suitable for system use and cover a wide variety of applications from test to R&D. Figure 3.1 shows the digital thermometer 7563.

Figure 3.1: Digital Thermometer 7563

3.1.2 ISOTECH Jupiter 650B

The Isotech Jupiter 650 B offers industry-leading performance in an easy-to-use portable package. With its wide temperature range, the Isotech Jupiter 650 dry block calibrator will reach that important 1200°F mark making it ideal for the calibration of thermocouples as well as platinum resistance thermometers. The Isotech Jupiter 650 dry block calibrator has been designed for fast heating and cooling for convenient field use. For flexibility, surface sensor and infrared thermometer accessories can be added.

Linear Process Inputs including 4-20mA current transmitters to be displayed on the built-in indicator. The Isotech Jupiter 650 dry block calibrator's SITE indicator is commonly used to display an external standard thermometer giving greater accuracy by eliminating temperature gradient and loading errors. Figure 3.2 shows the ISOTECH Jupiter 650B.

Figure 3.2: ISOTECH Jupiter 650B

3.1.3 Yokogawa Temperature Transmitter (PT100)

Temperature Transmitter use to convert thermocouple input to analog signals for direct interface with computer- based system. Temperature transmitter will accept the input from thermocouple and convert it to a 4 to 20mA signal for transmission. Signal from the thermocouple are very weak and can be easily affected by RFI and EMI interferences. These transmitters are robust and immune to RFI and EMI interferences. It also allows upscale and downscale temperature setting. User can set error correction and sensor failure detection if desire with ease. Figure 3.3 shows the Yokogawa Temperature Transmitter (PT100).

Figure 3.3: Yokogawa Temperature Transmitter (PT100)

3.1.4 Yokogawa digital manometer MT 220

The MT220 can measure temperature with outstanding accuracy, high resolution and excellent stability. It offers a wealth of functions for field calibration, including transmitter output measurement (DCV/DCA functions), 24-V DC output, percent error readout, measurement data memory, and Ni-Cd battery operation. Figure 3.4 shows the Yokogawa digital manometer MT220.

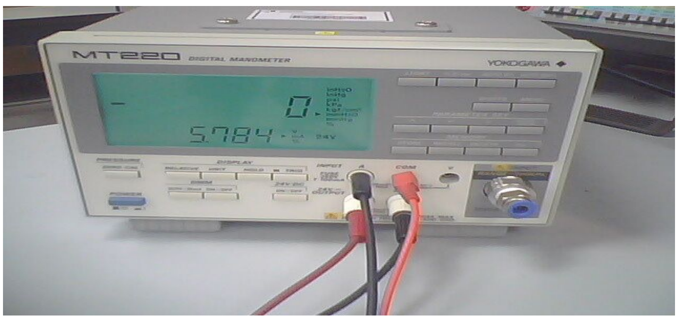

Figure 3.4: Yokogawa digital manometer MT 220

3.1.5 HART 375 Field Communicator

375 Field Communicator is the new standard in handheld communicators. It was universal HART® and Foundation TM field bus, intrinsically safe, rugged and reliable. Figure 3.5 shows HART 375 Field Communicator.

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Figure 3.5: HART 375 Field Communicator

3.1.6 2793 Decade Resistance Box

Model 2793 is high-accuracy, stable DC variable resistor with 6 dials and is available in two styles: 279301 for medium resistance from 0.1 to 1,111.210 Ω in 1 mΩ steps (best suited for calibration of resistance thermometers or bridges); 279303 for high resistance from 0 to 111.1110 MΩ in 100 Ω steps (suitable for calibration of insulation resistance testers or bridges).Figure 3.6 shows 2793 Decade Resistance Box.

Figure 3.6: 2793 Decade Resistance Box

3.2 Thermocouple Type K

Thermocouple is a temperature sensor that measure temperature by generating a small voltage signal proportional to the temperature difference between the junctions of two dissimilar metals. One junction (the hot junction) is typically encased in a sensor probe at the point of measurement; the other junction (the cold junction) is connected to the measuring instrument. The measurement instrument measures the voltage signal and the cold junction temperature then computes the temperature.

Type K is made from Chromel (Nickel-Chromium Alloy) for positive lead and Alumel (Nickel-Aluminium Alloy) for negative lead. This is the most commonly used "general purpose" thermocouples. They are available in the ~ -200 °C to +1200 °C range. Thermocouple type K shows by Figure 3.7.

Figure 3.7: Thermocouple Type K

3.3 Data Acquisition

Data acquisition cards are those cards that are used as interfaces between an instrument and a computer in order to capture data for temperature instrumentation. The 1710HG features 16 channels of analog input, two channels of analog output, a 68-pin connector and eight lines of digital I/O.

The PCI-1710 Series are multifunction cards for the PCI bus. Their advanced circuit design provides higher quality and more functions, including the five most desired measurement and control functions: 12-bit A/D conversion, D/A conversion, digital input, digital output, and counter/timer. Figure 3.8 shows PCI-1710HG.

Figure 3.8: PCI-1710 HG

3.4 Equipment Connection

24V power supply is connected to 4-20mA ammeter with series connection. Then negative side of power supply is connected to 2793 decade resistance box (250 ohm). Ammeter also connected to positive temperature transmitter while 2793 decade resistance box is connected to negative temperature transmitter. Next, HART 375 field communicator is connected parallel with temperature transmitter.

Meanwhile, Thermocouple type K is connected to temperature transmitter where positive thermocouple (red wire) is connected to pin number 2 of temperature transmitter, while white wire (-) of thermocouple is connected to pin number 1. The other one of thermocouple is functioned as reference. It connected to pin number 6 (for positive wire) and pin 5(for negative wire).

Temperature will detected by thermocouple and then thermocouple will send the input to temperature transmitter. The input from thermocouple will accepted by temperature transmitter and converted to a 4 to 20mA signal for transmission.

Then, the instrument is connected with the data acquisition (DAQ). DAQ that used in this project is PIC1710 HG which is the sampling of the real world to generate data that can be manipulated by a computer. The connection is show in figure 3.9.

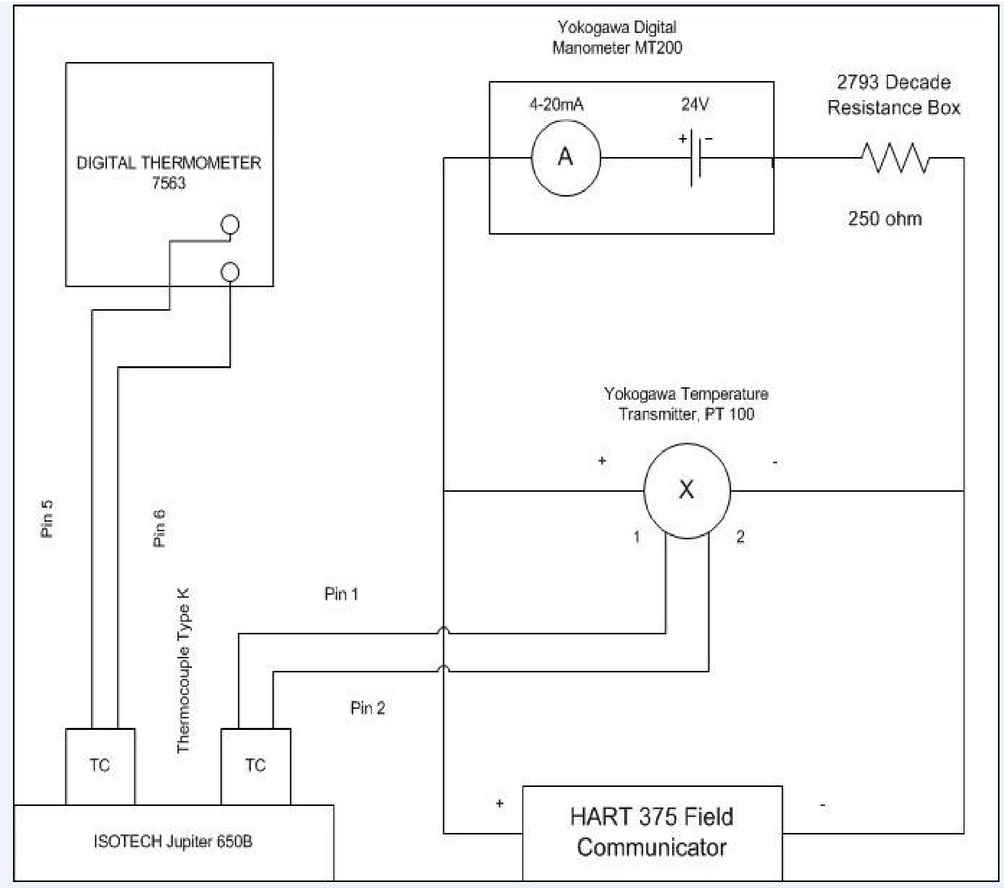

Figure 3.9**:** Equipment Connection

3.5 Block Diagram of the System

Refer to figure 3.10; DAQ (PCI1710HG) is used to interface the instrument with the system that has developed using MATLAB. SIMULINK model is used to run the DAQ and then data from instrument was transferred to MATLAB WORKSPACE. Data that transferred into workspace is captured and displayed at MATLAB GUI. Data that captures is used for calculation of average of actual output and output error. Meanwhile graph for five point calibration of temperature transmitter and output error versus MSU applied value are plotted and saved. Afterward, the data also used for uncertainty evaluation.

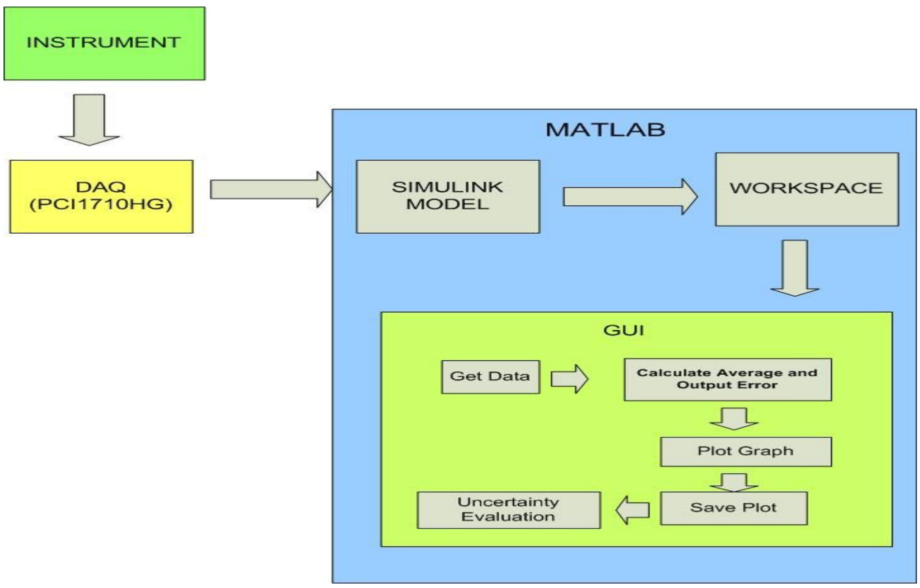

Figure 3.10: Block diagram of the system

APPENDIX D

PCI-1710HG DATA SHEET